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NACA

RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

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FLIGHT-TEST EVALUATION OF THE LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS OF 0.5-SCALE MODELS OF THE FAIRCHILD LARK PILOTLESS-AIRCRAFT CONFIGURATION. MODEL WITH WING FLAPS DEFLECTED 15°

TED No. NACA 2387

By

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Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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FLIGHT-TEST EVALUATION OF THE LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS OF 0.5-SCALE MODELS OF THE FAIRCHILD LARK PILOTLESS-AIRCRAFT CONFIGURATION. MODEL WITH WING FLAPS DEFLECTED 15°

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SUMMARY

A flight test was conducted at the Flight Test Station of the Pilotless Aircraft Research Division at Wallops Island, Va., to determine the longitudinal control and stability characteristics of a 0.5-scale model of the Fairchild Lark pilotless aircraft with the horizontal wing flaps deflected 15°. The data were obtained by the use of a telemeter and also by radar tracking. The results show an increase of effectiveness of the longitudinal control in producing normal accelerations up to a Mach number of 0.75 where this effectiveness gradually decreased becoming negative at a Mach number of 0.89. Previous tests with wing flaps undeflected showed an increase in effectiveness up to a Mach number of 0.93 where a sudden loss of control occurred. The model was dynamically stable throughout the speed range. The data confirmed the drag increase at the critical Mach number for large angles of attack as indicated in high-speed wind-tunnel tests.

INTRODUCTION

The NACA was requested by the Bureau of Aeronautics, Navy Department, to make flight tests of the Fairchild Lark pilotless-aircraft configuration to evaluate the longitudinal stability and control characteristics at high subsonic speeds in order to predict the behavior of the full-scale aircraft. In order to

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obtain this information 0.5-scale models, externally geometrically similar to the Fairchild Lark, were constructed and are to be flown at the Flight Test Station of the Pilotless Aircraft Research Division at Wallops Island, Va. This paper covers results of the flight of the second model. The results reported herein pertain to the longitudinal characteristics of the Fairchild Lark configuration with the horizontal wing flaps deflected down 15°. The model was flown with a programmed flicker-type deflection of the rudder elevators. This flight test was conducted July 24, 1946.

SYMBOLS

t time from launching, seconds

M free-stream Mach number

p free-stream static pressure

q free-stream dynamic pressure

H free-stream total pressure

C_N normal-force coefficient

C_C chord-force coefficient

W weight of model, pounds

S horizontal wing area, 2.725 square feet

a_l longitudinal acceleration, feet per second per second

a_n normal acceleration, feet per second per second

g acceleration of gravity, 32.2 feet per second per second

δ_e deflection of rudder elevators, degrees (trailing edge down is positive)

γ specific heat ratio; value taken, 1.4

δ_f deflection of horizontal-wing flaps, degrees

MODEL AND APPARATUS

The simplified 0.5-scale model used in this investigation was externally geometrically similar to the full-scale Lark (KAQ-1) of the Pilotless Plane Division of the Fairchild Engine and Airplane Corporation. A description of the 0.5-scale Lark models is given in reference 1.

Figure 1 presents a three-view drawing of the model whereas the general specifications of both the model and full-scale aircraft are given in table I. Photographs of the model and rocket motor with blast tube are shown in figure 2.

For this flight the rudder-elevators were deflected from approximately 0° up to -9° in a programmed movement to give a flicker-type operation. This control motion was in operation before the model left the launcher and all during the flight. Figure 3, a tail-view photograph of the model, shows the deflected control surfaces and the end of the blast tube.

The model was ground launched without a booster on a zero length launcher set at an angle of 45° from level. A photograph of the model on the launcher is shown in figure 4. At the time of the launching, the wind velocity was 4 miles per hour cross wind to the launcher.

The model weight was 127.4 pounds fully loaded and the corresponding center-of-gravity location was 18.58 percent of the wing chord. The model weight after burnout of the rocket motor was 99.9 pounds and the corresponding center-of-gravity location was 19.81 percent of the wing chord. The moment of inertia and the radius of gyration about the Y-axis for the model fully loaded were 8.3 slug-feet^2 and 1.45 feet, respectively. After burnout the moment of inertia was approximately 7.9 slug-feet^2 and the radius of gyration was 1.59 feet.

The data from the flight were obtained by the use of a telemeter, CW Doppler radar, and photography. The four-channel telemeter gave continuous signals of the longitudinal acceleration, normal acceleration, impact pressure, and the rudder-elevator position. The impact pressure record from the telemeter was reduced to Mach number by the following equation:

$$M^2 = \frac{2}{\gamma - 1}\left[\left(1 - \frac{H - p}{H}\right)^{-\frac{\gamma - 1}{\gamma}} - 1\right]$$

where p was taken as the pressure at sea level at the time of the test. The model reached an altitude of only about 500 feet. The velocity of sound for the test conditions was 1141 feet per second.

The normal-acceleration factor and the normal-force coefficient were based on a linear variation with time of the wing loading from the take-off condition to the burnout condition.

RESULTS AND DISCUSSION

A time history of the flight of a 0.5-scale model Fairchild Lark with the horizontal-wing flaps deflected 15° is presented in figure 5. This figure is a conversion of the telemeter record into curves of rudder-elevator deflection, Mach number, normal acceleration, and longitudinal acceleration against time from launching. The total elapsed flight time was 9.60 seconds. The maximum speed corresponded to a Mach number of 0.92 (rocket burnout) at a time of 3.70 seconds after launching. The dashed part of the Mach number curve was obtained by integration of the longitudinal-acceleration curve.

Referring to figure 5, it may be seen that the normal acceleration, with the usual short-period oscillations, followed the deflection of the rudder-elevators until a Mach number of 0.75 was reached ($t \approx 2.6$). With approximately 8.5° up elevator, the normal acceleration changed from a positive value of about 20g at $M = 0.75$ to a negative value of 5g at $M = 0.92$. As the speed decreased from $M = 0.92$ ($t \approx 4.2$), the longitudinal control was gradually reestablished. Control was fully restored when the speed decreased to $M = 0.75$ ($t \approx 5.3$). The results show an increase of effectiveness of the longitudinal control in producing normal accelerations up to $M = 0.75$ where this effectiveness gradually decreased becoming negative at $M = 0.89$. Previous tests, reference 1, with wing flaps not deflected, showed an increase in effectiveness up to $M = 0.93$ where a sudden loss of control occurred.

The ability of the rudder-elevators to produce normal acceleration is shown in figure 6 as a plot of normal-acceleration factor $\left(\frac{a_n}{g}\right)\left(\frac{1}{\delta_e}\right)\left(\frac{W}{S}\right)$ against Mach number. The accelerations used to determine the variation of the normal-acceleration factor were obtained by fairing out the transient oscillations due to the abrupt rudder-elevator deflections. The normal-acceleration factor was computed only for up rudder-elevator deflections since at $\delta_e = 0^\circ$ the model was not maneuvering. Also shown on figure 6 is the curve of normal-acceleration factors for the flight test with $\delta_f = 0^\circ$ (reference 1). The difference between the power-on and power-off curves is probably due to the rapidly changing values of the slope of the pitching-moment curve at high lift coefficients in this Mach number region as shown in high-speed wind-tunnel tests of a 0.25-scale model (reference 2). The difference between the $\delta_f = 0^\circ$ curve and the $\delta_f = 15^\circ$ curve includes the effects of different center-of-gravity locations (approximately 2 percent mean aerodynamic chord) and the different values of the slope of the pitching-moment curves for high and low lift coefficients. In order to obtain the normal acceleration produced per degree of rudder-elevator deflection for any desired wing loading, divide the normal-acceleration factor by this wing loading. For example, at $M = 0.75$, the following comparisons may be made:

δ_f (deg)	0.5-scale model			Full-scale aircraft		
	W/S (lb/sq ft)	Center of gravity (percent chord)	a_n/g per δ_e	W/S (lb/sq ft)	Center of gravity (percent chord)	a_n/g per δ_e
0	38.9	16.64	-0.86	110	16.64	-0.30
15	36.6	19.81	-1.95	110	19.81	-0.65

Referring to figure 6 it may be seen that for $M = 0.83$ and greater, the lift capabilities are greater without the wing flaps deflected than with a deflection of 15°. Figure 7 presents the variation of normal-force coefficient with Mach number for the power-on flight period. The maximum value of C_N obtained is near the stalled region for the Lark configuration as determined from reference 2.

The model in flight exhibited dynamic stability throughout the speed range as the short-period oscillations induced by the abrupt elevator movements were always damped as shown by the normal-acceleration curve in figure 5.

Figure 8 presents curves of chord-force and normal-force coefficients for the power-off decelerating part of the flight. The results of high-speed wind-tunnel tests of a 0.25-scale model (reference 2) show an increase in drag coefficient at $M = 0.75$ at high angles of attack with the wing flaps deflected 15°. At a corresponding Mach number as shown in figure 5, the decrease in the longitudinal acceleration at the high normal acceleration indicates the drag increase. Referring to figure 8 the higher value of C_C above $M = 0.75$ as compared to those at lower values of M also indicates the drag increase.

CONCLUSIONS

The flight test to determine the longitudinal stability and control characteristics with the horizontal wing flaps deflected down 15° for the Fairchild Lark pilotless aircraft was conducted at the Flight Test Station of the Pilotless Aircraft Research Division at Wallops Island, Va. From the results of this flight test, the following general conclusions are indicated:

1. Increase of effectiveness of the rudder-elevators as longitudinal control in producing normal accelerations up to $M = 0.75$ where this effectiveness gradually decreased becoming negative at $M = 0.89$. Previous tests with wing flaps undeflected showed an increase in effectiveness up to $M = 0.93$ where a sudden loss of control occurred.

2. The model exhibited dynamic stability throughout the speed range.

3. The decrease in longitudinal acceleration at high normal accelerations confirms the drag increase for $\delta_f = 15^\circ$ in the vicinity of $M = 0.75$ at large angles of attack as indicated in high-speed wind-tunnel tests.

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Approved:
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MEL

REFERENCES

1. Stone, David G., and Mitcham, Grady L.: Flight-Test Evaluation of the Longitudinal Stability and Control Characteristics of 0.5-Scale Models of the Fairchild Lark Pilotless-Aircraft Configuration. Model with Wing Flaps Not Deflected. TED No. NACA 2387. NACA MR No. L6H22, Bur. Aero., 1946.

2. Smith, Norman F.: High-Speed Tests of 1/4-Scale Model of Navy Special Missile Lark. NACA MR No. L5H01, Bur. Aero., 1945.

TABLE I.- GENERAL SPECIFICATIONS

Item	Full-scale aircraft	0.5-scale model
Fuselage:		
Over-all length, in.	164	82
Maximum diameter, in.	17	8.5
Wings:		
Aspect ratio	3.49	3.49
Total span, in.	74	37
Chord (constant), in.	21.2	10.6
Angle of incidence, deg	0	0
Dihedral, deg	0	0
Sweep, deg	0	0
Airfoil section:		
Horizontal wing	NACA 16-209	NACA 16-209
Vertical wing	NACA 16-009	NACA 16-009
Wing area (per pair including fuselage), sq ft	10.9	2.725
Tail surfaces:		
Span, in.	48	24
Chord (constant), in.	15.4	7.7
Angle of incidence, deg	0	0
Dihedral, deg	45	45
Sweep, deg	0	0
Airfoil section	NACA 16-008	NACA 16-008
Total projected area, sq ft	7.25	1.813
Propulsion:		
Type rocket	Liquid	Powder
Approximate thrust, lb	600	1300
Approximate duration, sec	220	3.7
c.g. location, percent chord	20	Take-off, 18.58 Burnout, 19.81
Weight, lb	1060	Take-off, 127.4 Burnout, 99.9
Wing loading, lb/sq ft	110	Take-off, 46.7 Burnout, 36.6

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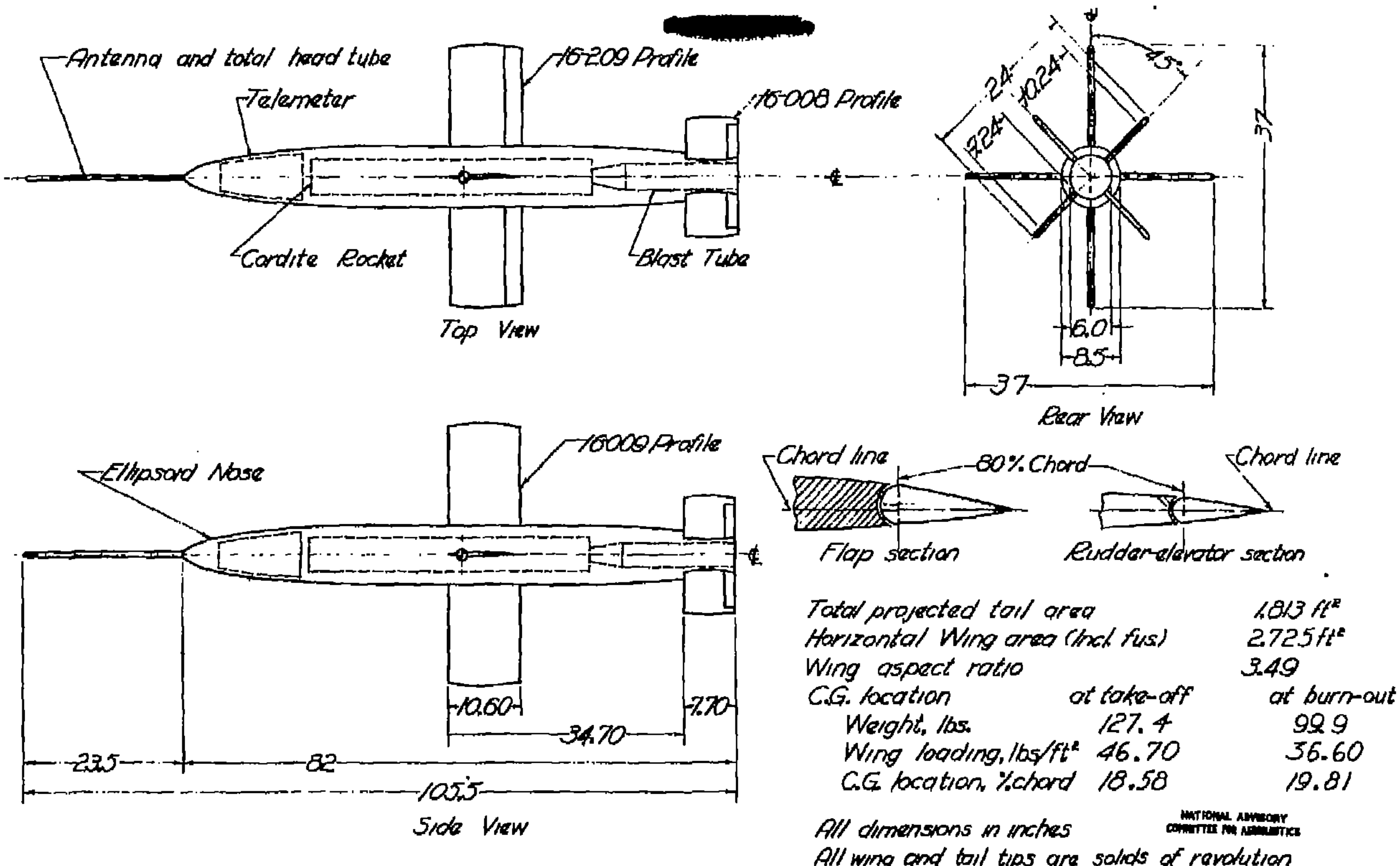

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Figure 1.-Three view drawing of 0.5-scale model of Fairchild Lark Pilotless Aircraft.

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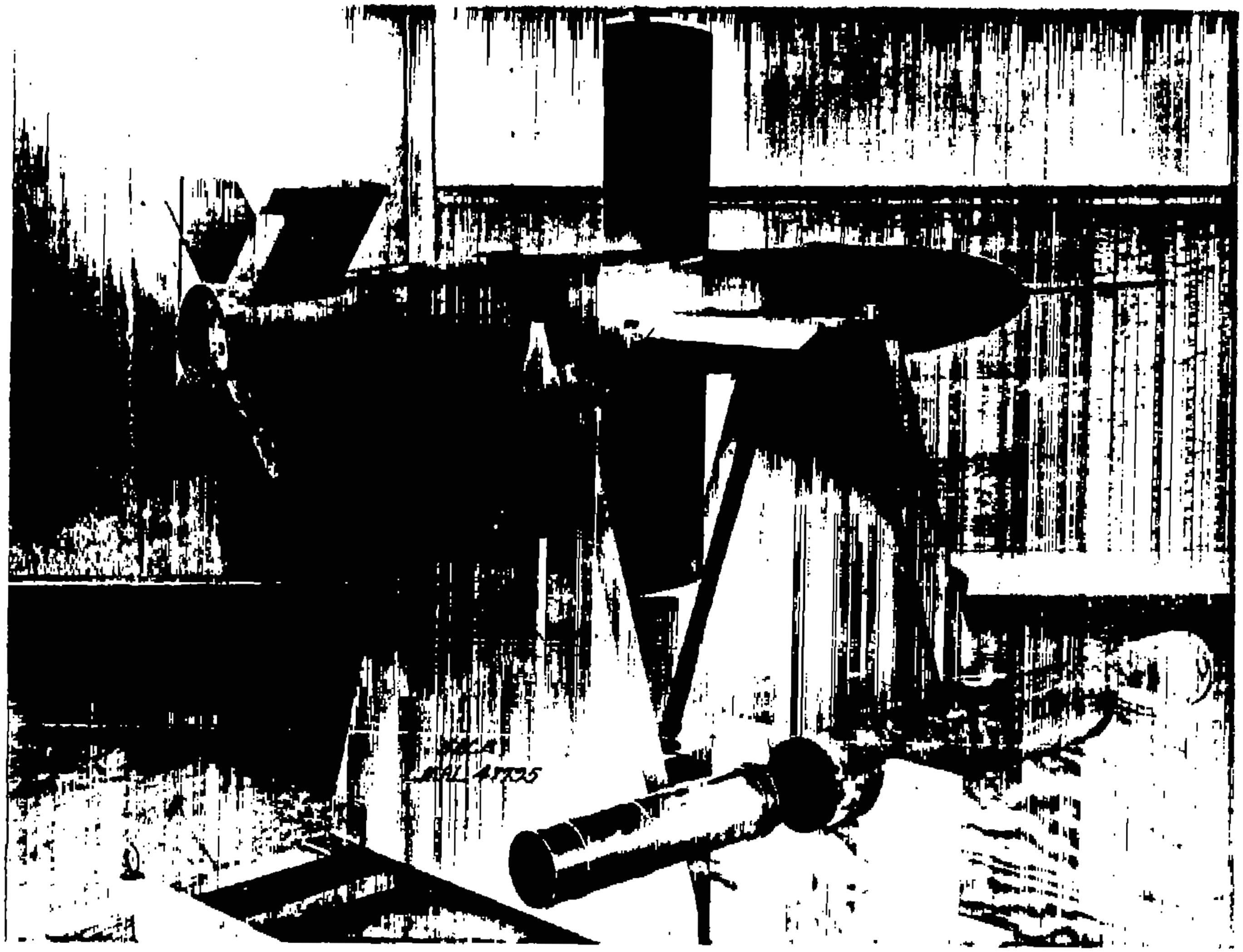

Figure 2.- Photographs of 0.5-scale model Lark and rocket motor with blast tube.

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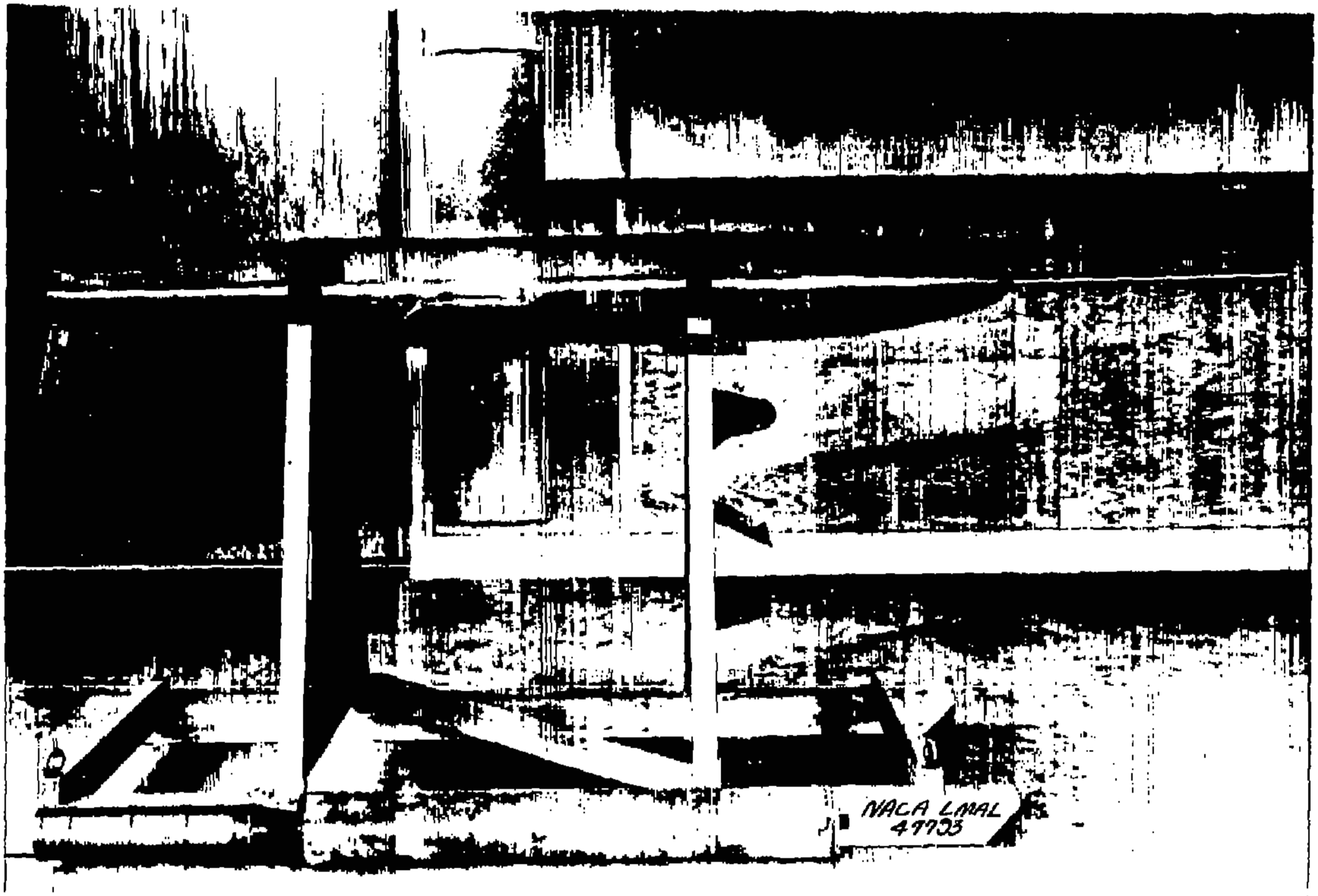

Figure 2.- Concluded.

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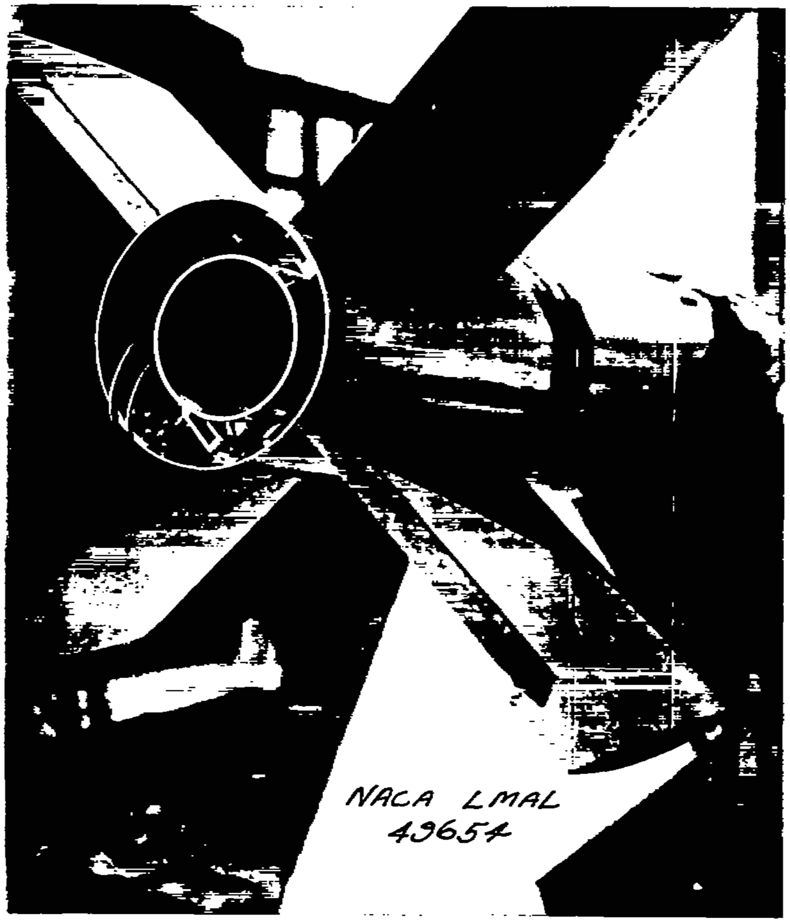

Figure 3.- Tail-view photograph of a 0.5-scale model Lark.

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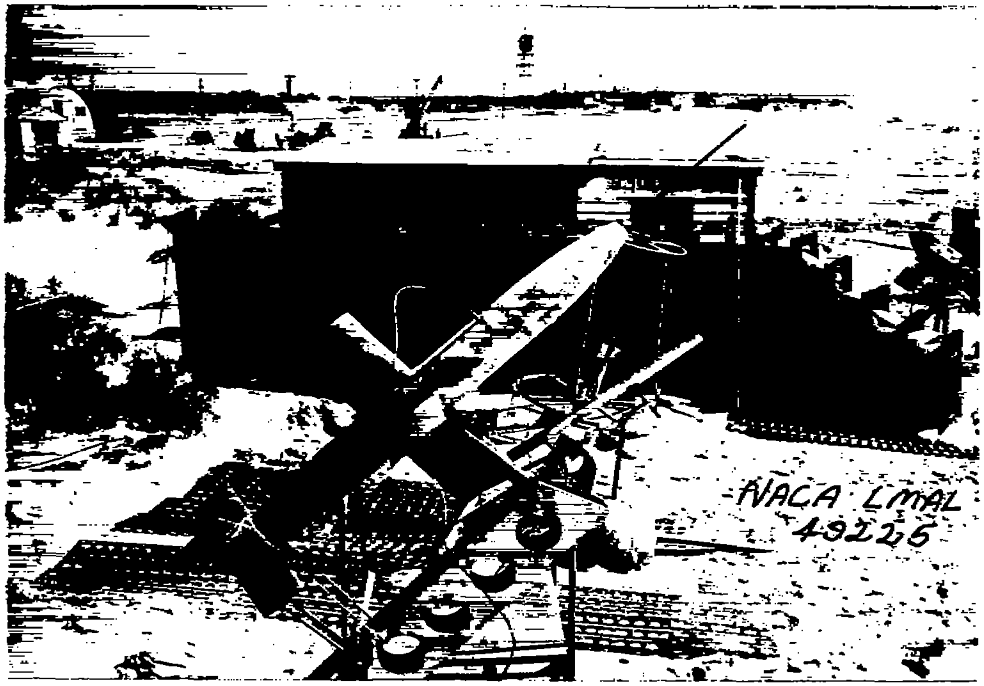

Figure 4.- Photograph of a 0.5-scale model Lark on launcher.

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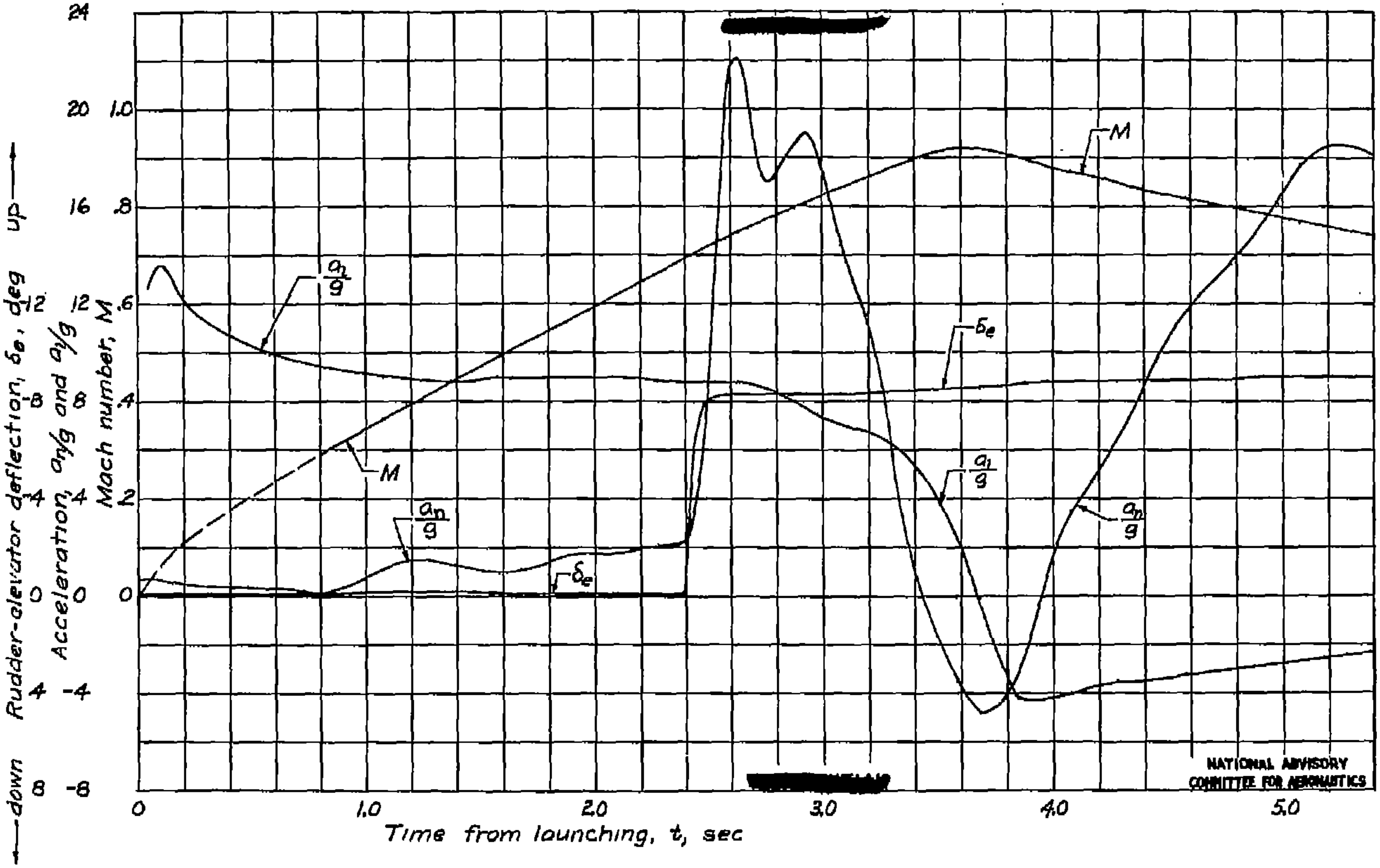

Figure 5.- Variation of Mach number, rudder-elevator deflection, and normal and longitudinal accelerations with time for the flight with $\delta_f = 15°$

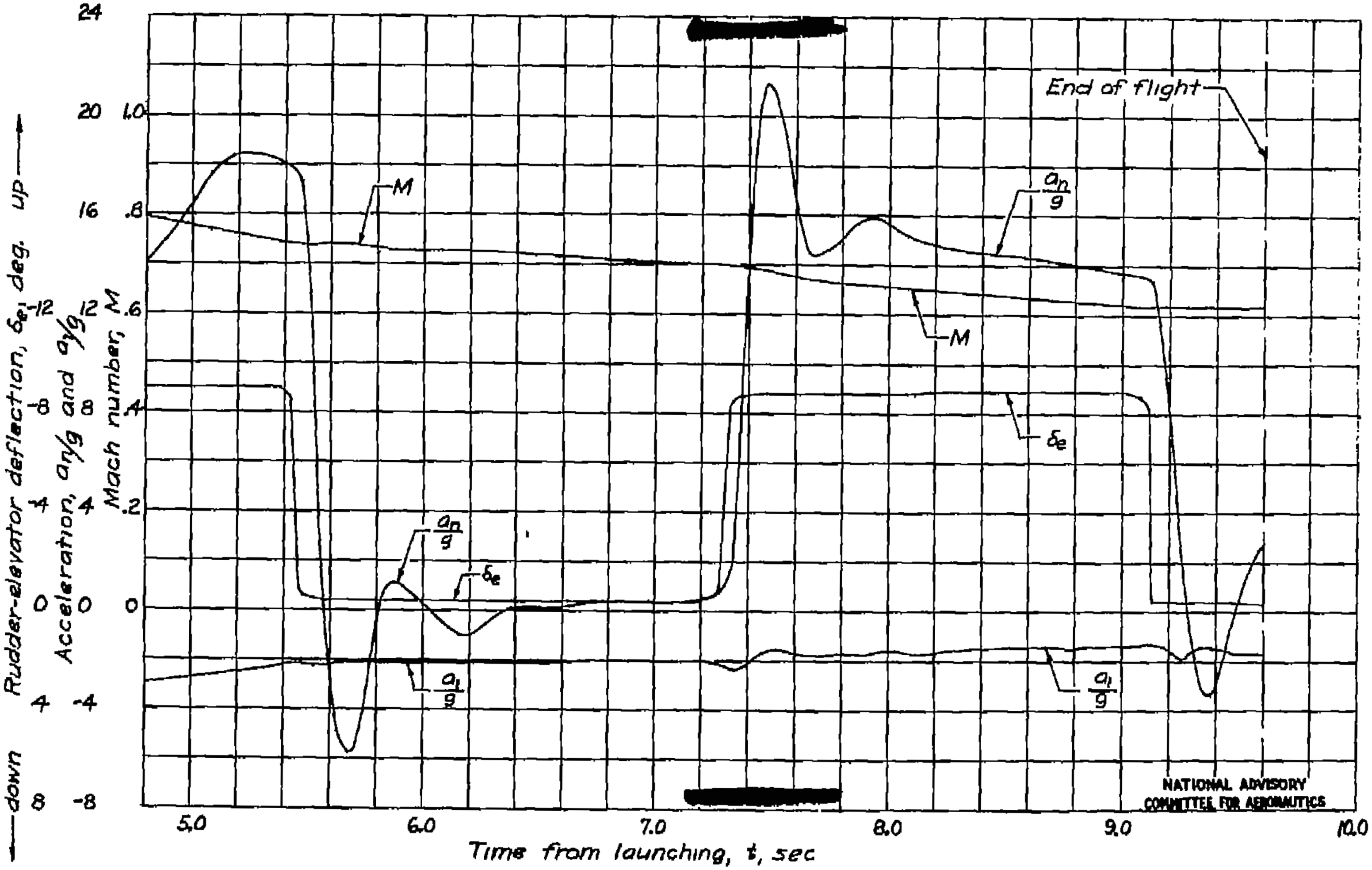

Figure 5.- Concluded.

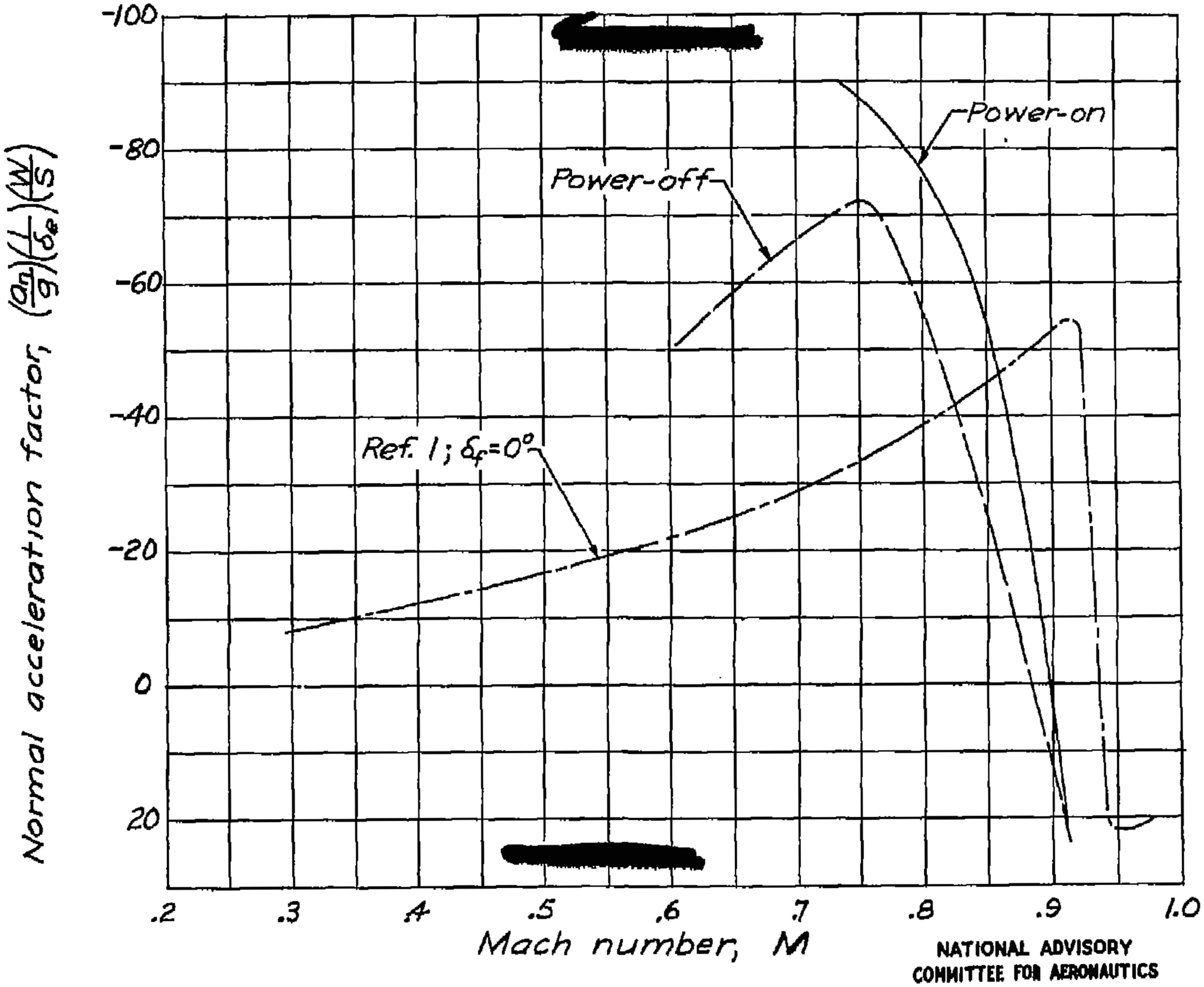

Figure 6.- Variation of normal acceleration with Mach number for flight with $\delta_f = 15°$.

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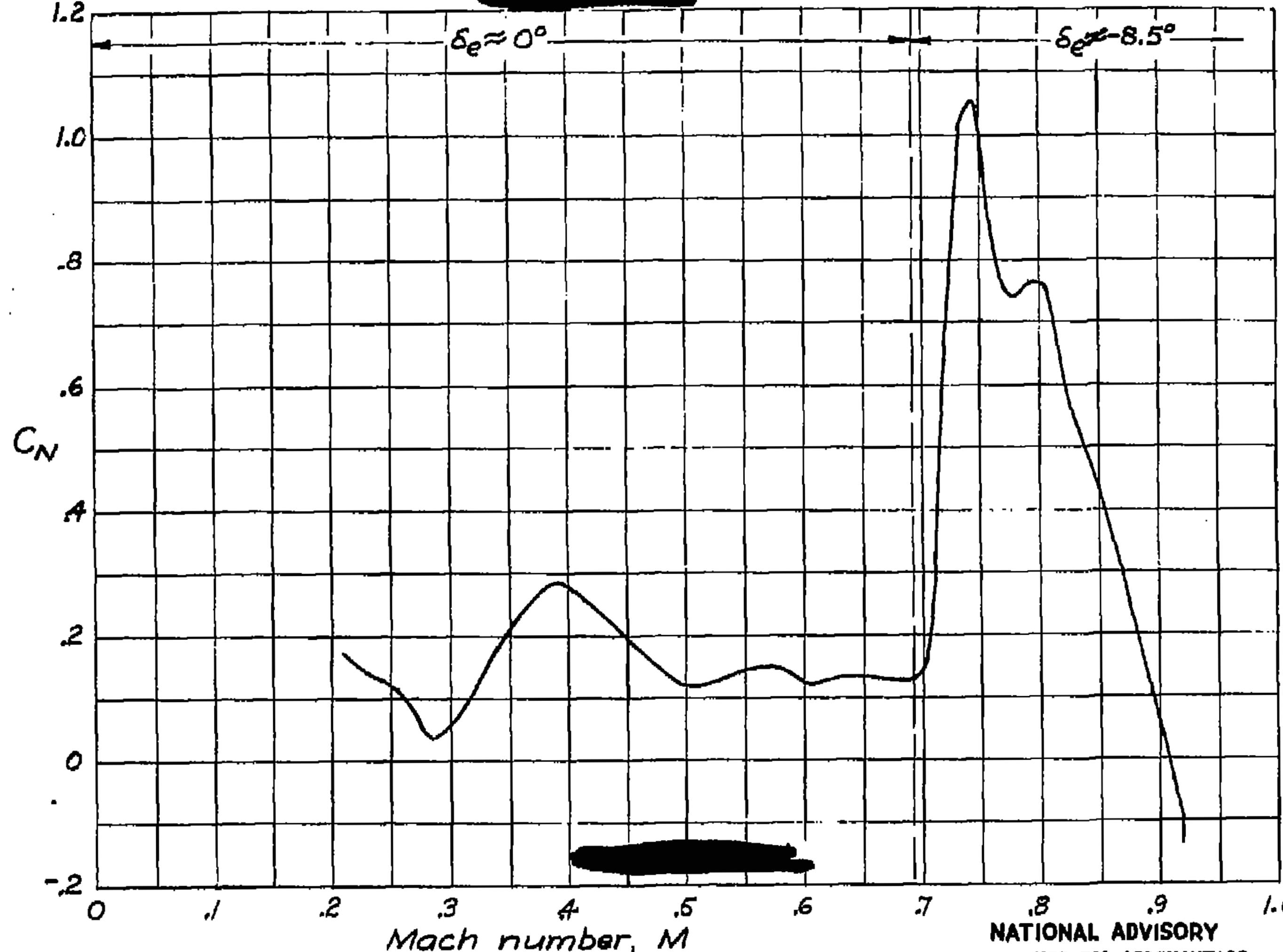

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Figure 7.- Variation of normal-force coefficient with Mach number for the power-on portion of the flight with $\delta_f = 15°$.

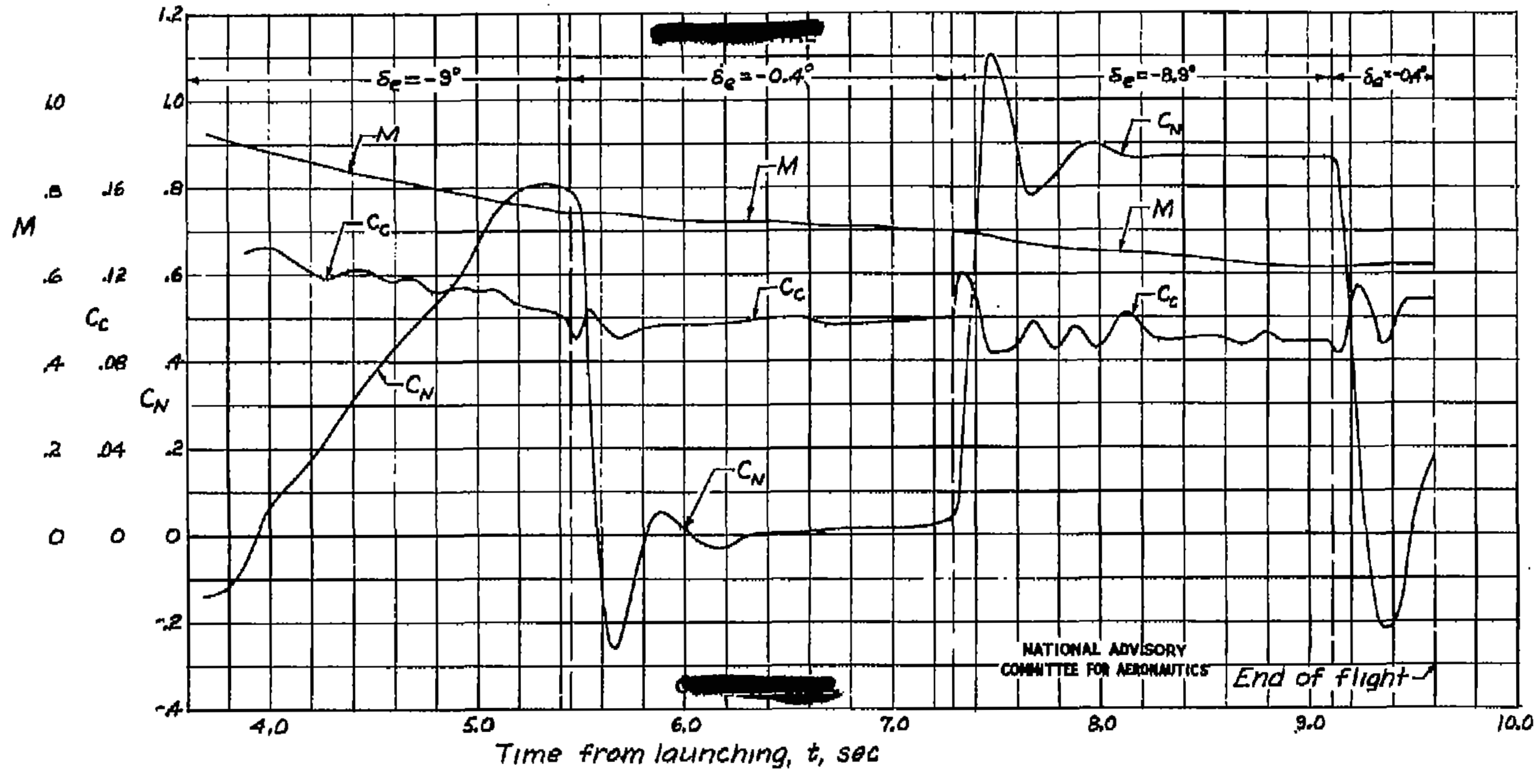

Figure 8.- Variation of Mach number and chord-force and normal-force coefficients with time for the power-off portion of the flight with $\delta_f = 15°$.